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PROJECT APOLLO

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SUN-IN-THE-WINDOW ANALYSIS FOR THE APOLLO 7 NOMINAL LAUNCH PHASE AND THE MODE III, FIXED-ΔV, AND MODE IV ABORTS

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SUMMARY

A study was made to determine if the crew for the Apollo 7 mission will be exposed to sunlight through the command module (CM) forward viewing windows during the nominal launch phase or for mode III, fixed-ΔV, and mode IV aborts. Sun conditions during the nominal launch phase and the various abort modes were examined throughout the launch window, from August through December, 1968.

It was determined that a sun problem is present only for early launch dates (August 1st through approximately September 5) and launch times for the nominal launch phase. No sun problem existed for the mode III, fixed-ΔV, and mode IV aborts.

INTRODUCTION

This study was conducted to evaluate the launch window to determine if sunlight could be expected to enter through the CM forward viewing windows during the Apollo 7 (Mission C, or AS-205/CSM-101) nominal launch phase or for the mode III, fixed-ΔV, and mode IV aborts. Sunlight may interfere with crew activities during the nominal launch phase and present adverse conditions for performing various duties.

Data on which this study is based consist of that for the defined launch window, definition of the field-of-view through the CM forward viewing windows, and the initial conditions originating from a nominal launch trajectory for the launch phase and a launch abort study for the abort modes.

Where a sun-in-the-window problem was found to exist, figures are presented showing a time history of the movement of the sun vector through the CM windows. Where the sun was of interest during launch aborts, the position of the sun vector is shown at the time of service propulsion subsystem (SPS) ignition and while an inertial attitude is maintained during the SPS burn.

SUPPORTING DATA FOR THE ANALYSIS

Launch Window

The launch window used for the consideration of sunlight in the CM windows is defined in reference 1. This launch window encompasses the months of August through December 1968. For all launch dates the launch window opens at 10:00 a.m., e.s.t., and closes at approximately 3:00 p.m., e.s.t., for an August 1, 1968, launch and at approximately 1:54 p.m., e.s.t., for a December 1, 1968, launch.

Crew Field of View

The field of view for the commander (left forward viewing window) and the CM pilot (right forward viewing window) is given in reference 2. The reference contains the field of view through the CM-101 forward viewing windows for the eye positions of the 10th, 50th, 80th, and 90th percentile man. The Apollo 7 commander and pilot are approximately 75 percentile, and the field of view available for the 80th percentile eye position has been used in this analysis. This field of view is valid for the unitized couch (CM-101) and an A7L pressure garment assembly.

Spacecraft coordinate systems for sun-look angles during the nominal launch phase, mode III and fixed-ΔV aborts, and mode IV aborts are presented in figures 1, 2, and 3, respectively. The position of the sun vector with respect to the Apollo 7 spacecraft is defined in terms of the sun-look angles, theta (θ_S) and phi (ϕ_S), and has been transposed to the CM forward viewing windows in terms of these same angles for the nominal launch phase, figure 4, and fixed-ΔV aborts, figure 5. Note that the small obstructed area of the field of view by the boost protective cover in the lower portion of the forward viewing windows has not been considered.

Initial Conditions

Examination of the position and movement of the sun vector through the CM forward viewing windows during the nominal launch phase (lift-off through spacecraft insertion) was conducted with the updated nominal Apollo 7 launch trajectory (ref. 3).

Initial conditions (spacecraft position and attitude) for the examination of the possibility of the sun vector passing through the CM forward viewing windows during mode III, fixed-ΔV, and mode IV aborts were those used in the launch abort study for Apollo 7, (ref. 4). State vectors at initiation of the SPS burn reflecting current abort philosophy were used in all cases for the analyses of the abort modes.

RESULTS

Launch Phase

The launch window is for the dates of August 1, 1968 through December 31, 1968, and the launch window opens at 1500 G.m.t. (10:00 a.m., e.s.t.) on all possible launch dates. An analysis of the sun vector position and movement through the left and right forward viewing windows for all possible launch dates and launch times was made from lift-off through spacecraft insertion.

Figure 1 shows the spacecraft coordinate system for the computation of sun-look angles during the nominal launch phase. Figure 4 is a transposition of the sun-look angles to the CM forward viewing windows. It was found that the sun vector passes through the commander's forward viewing window (left forward viewing window) for various periods of time for launches occurring between August 1 and approximately September 5. Referring to figure 4 (a), for a launch on August 1 at 1500 G.m.t., the sun vector enters and exits the field of view twice making the second exit at 78 seconds ground elapsed time (g.e.t.). For a launch on August 1 at 1700 G.m.t., the sun vector is in the field of view at lift-off and exits from view at 30 seconds g.e.t. For a luanch after approximately 1730 G.m.t. on August 1 (or any launch date), the sun does not appear in the commander's forward viewing window. Similarly, for a launch after approximately September 5, the sun does not appear in the commander's forward viewing window for any launch time.

Figure 4 (b) is a history of the position and movement of the sun vector through the CM pilot's right forward viewing window.

Mode III Aborts

Although the mode III abort region begins at approximately 9^m31^s g.e.t. (earliest time a mode III abort would be performed), the mode III abort region requiring an SPS burn in which a fixed inertial attitude is maintained (i.e., the CSM is oriented in a retrograde attitude 31.7° below the line of sight to the horizon of the earth) begins at approximately 9^m35^s g.e.t. and continues past insertion.

Figure 2 shows the spacecraft coordinate system and spacecraft initial attitude for the computation of sun-look angles during a mode III abort.

Worst possible sun conditions for mode III aborts exist for aborts occurring late in the mode III region (just prior to or past insertion) and near the close of the launch window. At this time the sun is at the lowest possible point above the horizon of the earth.

Sun conditions were examined throughout the launch window for a representative mode III abort occurring late in the mode III region at 10^m01^s g.e.t. It was found that the angle the sun vector makes with the spacecraft longitudinal axis (X-axis) is never less than 65°. Thus, the sun does not present a problem for performing mode III aborts.

Fixed-ΔV Aborts

This abort mode is for the near- and post-insertion region where the ignition for the SPS burn, at a fixed inertial attitude (i.e., the CSM is oriented in a retrograde attitude 31.7° below the line of sight to the horizon of the earth) with a fixed magnitude ΔV, is delayed to allow a landing in the Indian Ocean Recovery Area. Hence, fixed-ΔV aborts are those requiring a maximum delay time for underspeed trajectories (earliest time a fixed-ΔV abort can be performed) and a minimum delay time for overspeed trajectories.

The ground elapsed time of abort corresponding to a maximum time delay is 9^m52^s and SPS ignition occurs at 33^m26^s. The ground elapsed time of abort corresponding to a minimum time delay is 10^m3^s and SPS ignition occurs at 12^m8^s. (The time between time of abort and SPS ignition is not less than 2 minutes 5 seconds, the minimum time delay.) Assuming a nominal insertion into the parking orbit, the latest that a fixed-ΔV abort can be performed corresponds to a ground elapsed time at SPS ignition of 26^m36^s.

For purposes of this analysis, the worse possible sun conditions for performing fixed-ΔV aborts would exist for aborts requiring a maximum time delay (SPS ignition occurs at 33^m26^s g.e.t.). Again, at this time the sun is at the lowest possible point above the horizon of the earth. It was not necessary to consider fixed-ΔV aborts for overspeed trajectories (minimum time delay) or from orbit after nominal insertion. A fixed-ΔV abort for overspeed trajectories corresponds to a late mode III abort (already examined), and a fixed-ΔV abort after nominal insertion corresponds to a maximum-time-delay, fixed-ΔV abort (under consideration).

Figure 2 shows the spacecraft coordinate system and spacecraft initial attitude for the computation of sun-look angles during a fixed-ΔV abort. Figure 5 shows the most significant results for the examination of the sun conditions throughout the launch window for a maximum time delay, fixed-ΔV abort occurring at 9^m52^s g.e.t. It was found that the sun does not present a problem although the angle the sun vector makes with the spacecraft longitudinal axis (X-axis) is 33° for a launch on August 1, 1968, at 1641 G.m.t. Further, it may be noted that the sun is below the horizon and that the spacecraft enters darkness for maximum-time-delay, fixed-ΔV aborts occurring between a launch time of 1600 and 1700 G.m.t. (11:00 a.m. and 12:00 a.m., e.s.t.) and later.

Mode IV Aborts

The mode IV abort (contigency orbit insertion) region begins at 9^m26^s g.e.t. (the earliest ground elapsed time that a mode IV abort can be performed). For a mode IV abort the spacecraft is orientated to a posigrade attitude of 31.7° above the line of sight to the horizon of the earth.

Figure 3 shows the spacecraft coordinate system and spacecraft initial attitude for the computation of sun-look angles during a mode IV abort. Worst possible sun conditions exist for aborts occurring early in the mode IV abort region and near the opening of the launch window when the sun is rising above the horizon of the earth.

Sun conditions were examined throughout the launch window for a representative mode IV abort occurring at the beginning of the mode IV abort region at 9^m29^s g.e.t. It was found that the angle the sun vector makes with the spacecraft longitudinal axis (X-axis) is never less than 64°. The sun does not present a problem for performing mode IV aborts.

CONCLUSION

This study was conducted to determine if the crew (commander and CM pilot) for the Apollo 7 mission would be exposed to direct sunlight throughout the launch window during the nominal launch phase, or mode III, fixed-ΔV, and mode IV aborts. The results are based upon the launch window, the crew's field of view through the CM-101 forward viewing windows, nominal launch trajectory, and abort philosophy which are currently defined for the mission.

An examination of the sun conditions revealed that the commander is exposed to the sun vector early (time of launch) in the launch window during the nominal launch phase for launches occurring between August 1 and approximately September 5, 1968. The CM pilot is exposed to the sun vector early in the launch window during the nominal launch phase for launches occurring between August 1 and approximately August 20, 1968.

Neither the commander nor CM pilot is exposed to the sun vector for mode III, fixed-ΔV, or mode IV aborts throughout the launch window. However, it was noted that the spacecraft is in darkness for maximum-time-delay, fixed-ΔV aborts that may occur between a launch time of 1600 and 1700 G.m.t. (11:00 a.m. and 12:00 a.m., e.s.t.) and later.

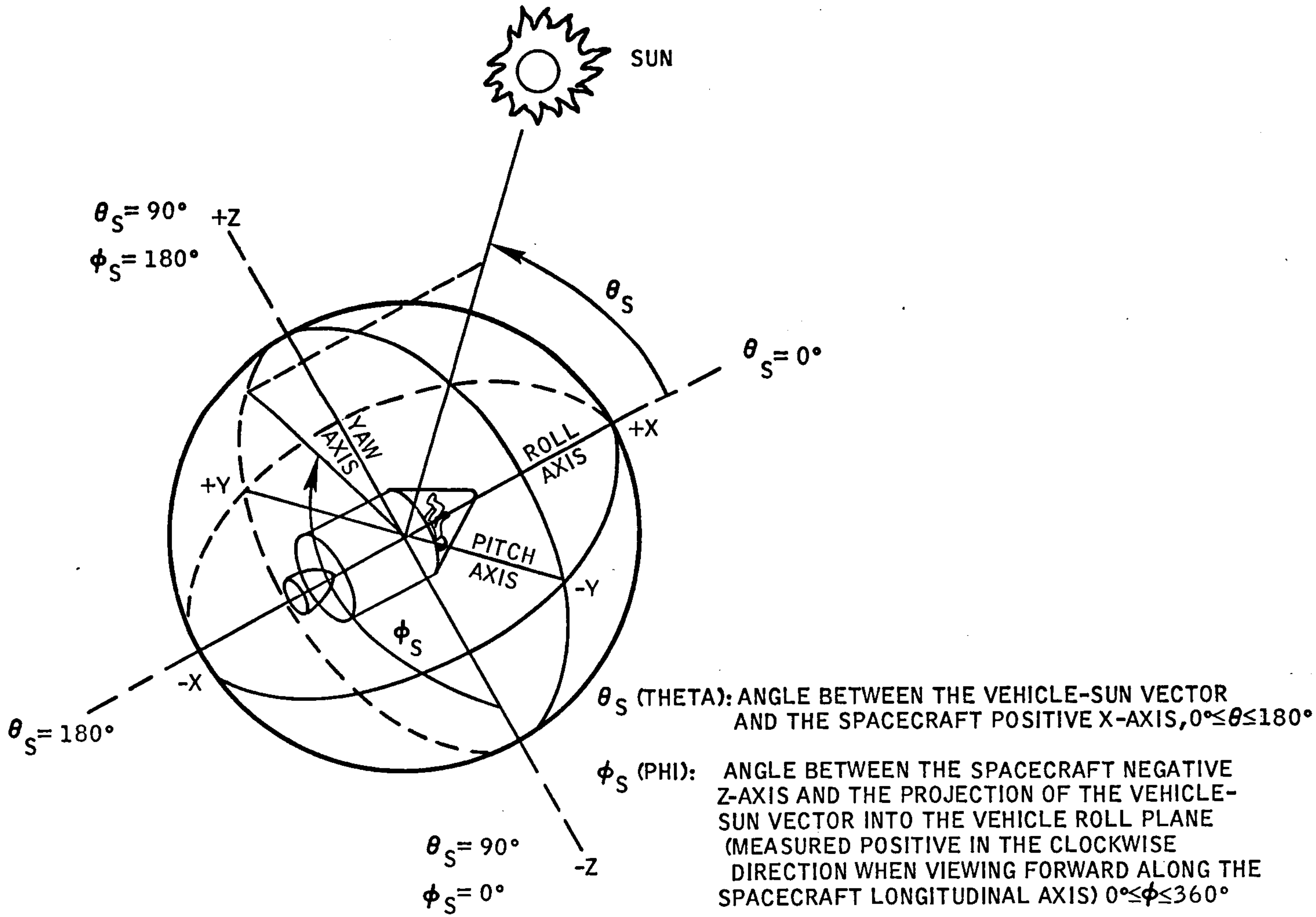
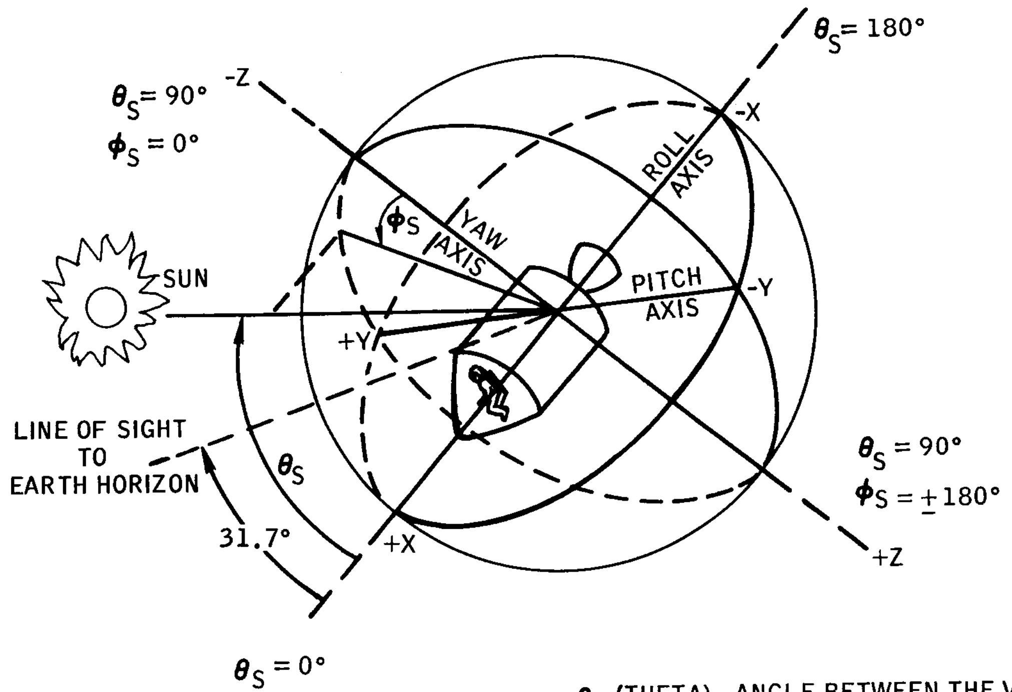


Figure 1. - Spacecraft coordinate system for sun-look angles during nominal launch phase.



θ_S (THETA): ANGLE BETWEEN THE VEHICLE-SUN VECTOR AND THE SPACECRAFT POSITIVE X-AXIS, $0° \leq \theta \leq 180°$

ϕ_S (PHI): ANGLE BETWEEN THE SPACECRAFT NEGATIVE Z-AXIS AND THE PROJECTION OF THE VEHICLE-SUN VECTOR INTO THE VEHICLE ROLL PLANE (MEASURED POSITIVE IN THE CLOCKWISE AND NEGATIVE IN THE COUNTER-CLOCKWISE DIRECTION WHEN VIEWING FORWARD ALONG THE SPACECRAFT LONGITUDINAL AXIS) $0° \leq \phi \leq 180°$

Figure 2.- Spacecraft coordinate system for sun-look angles during mode III and fixed ΔV aborts.

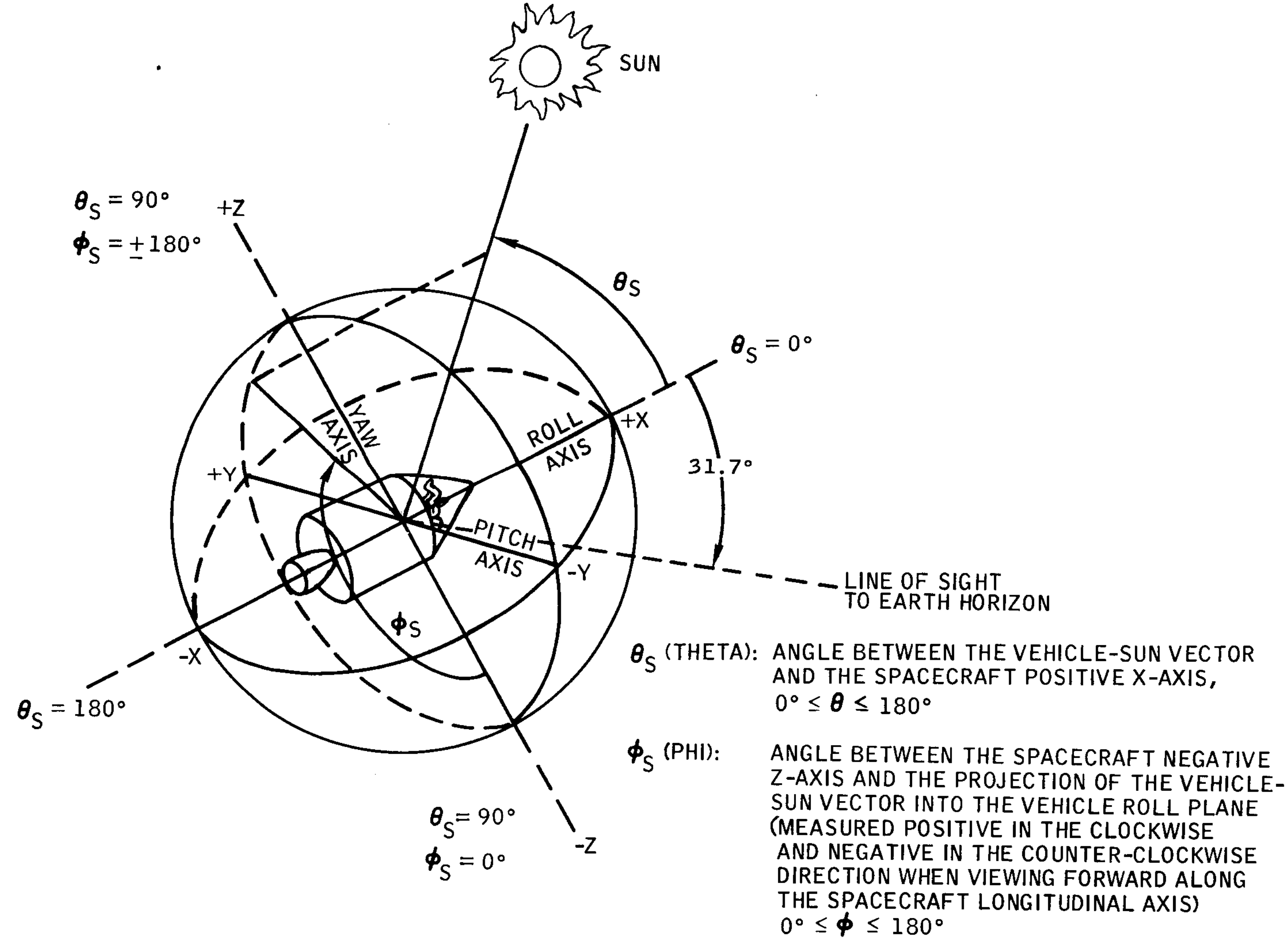
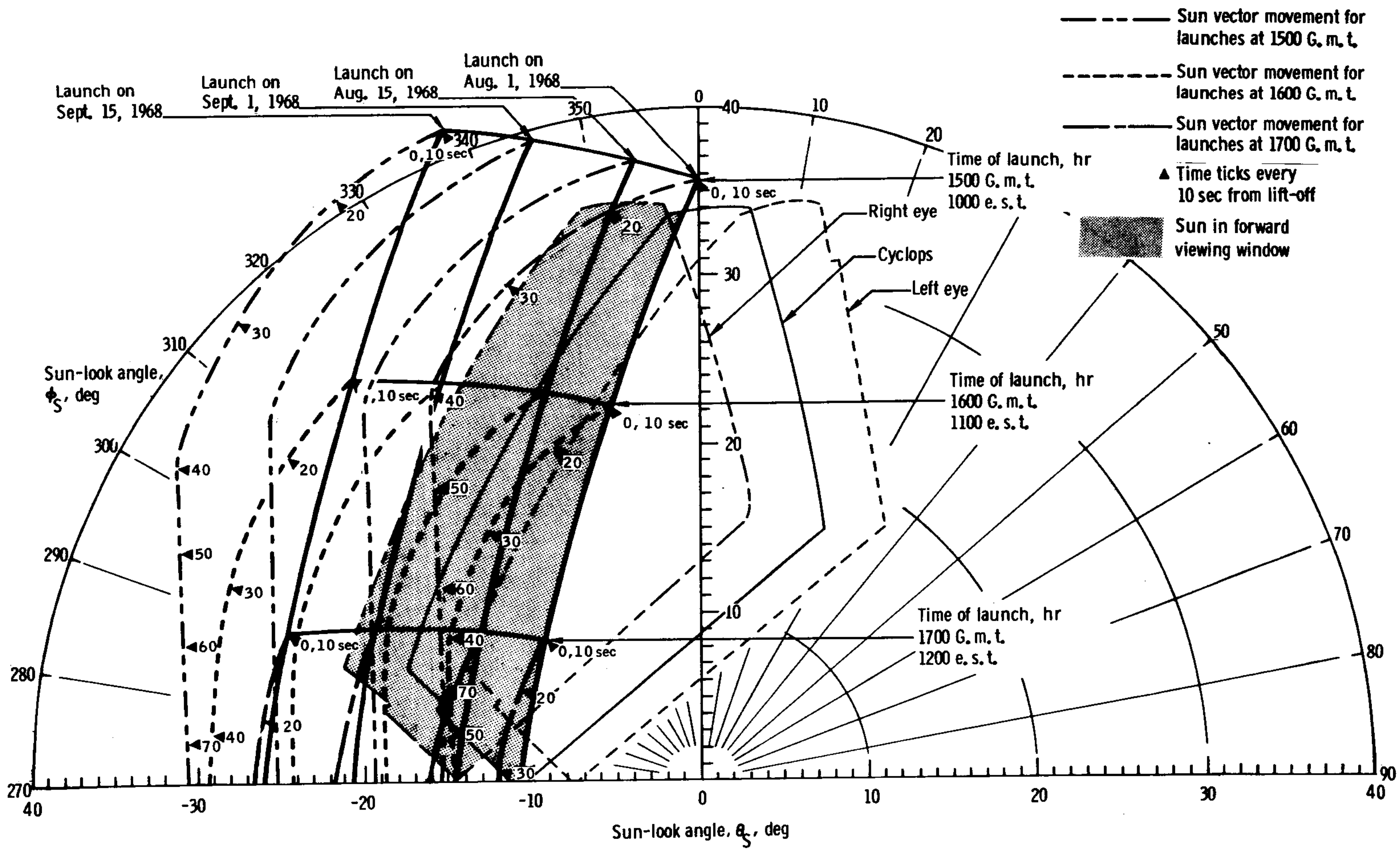
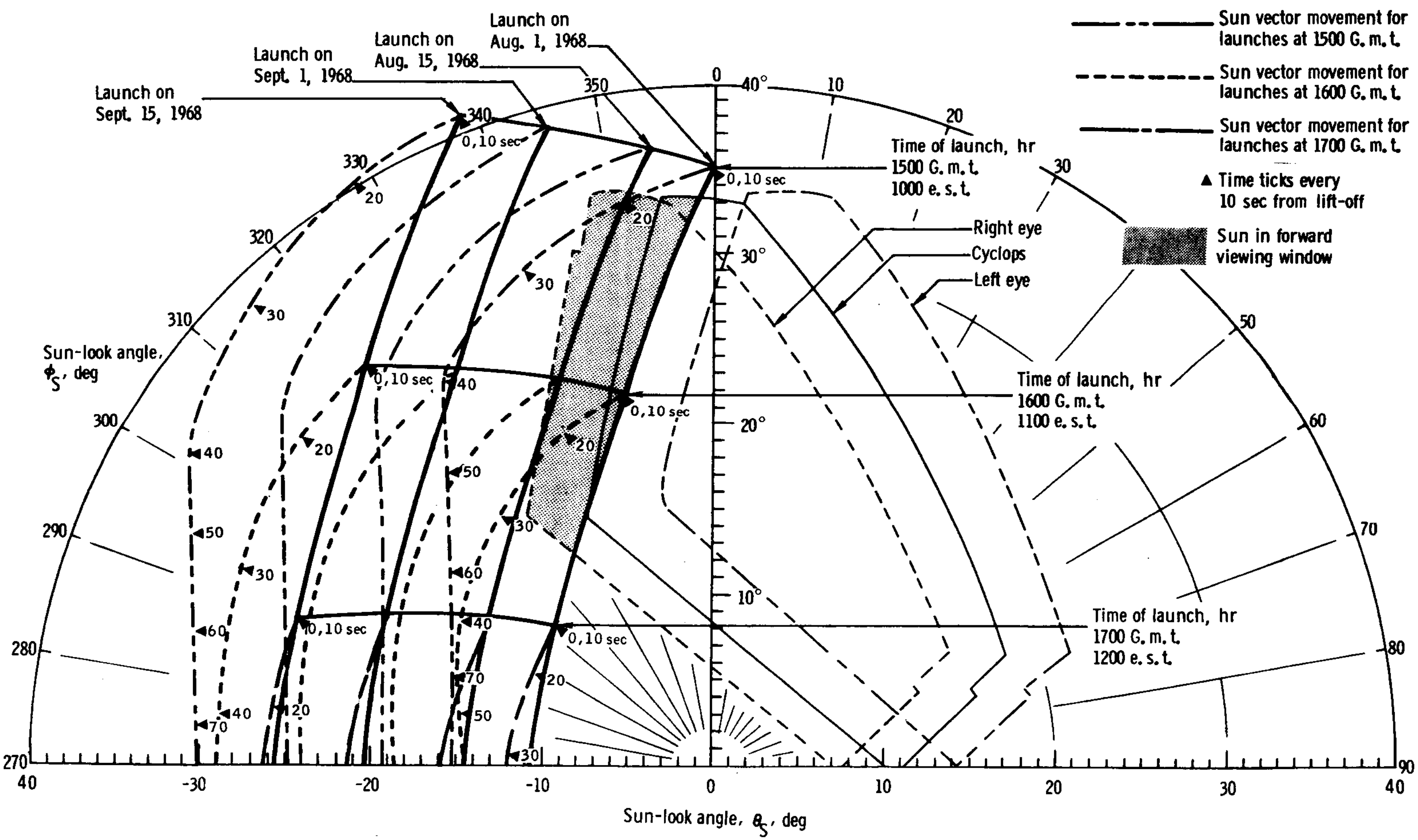


Figure 3.- Spacecraft coordinate system for sun-look angles during mode IV aborts.



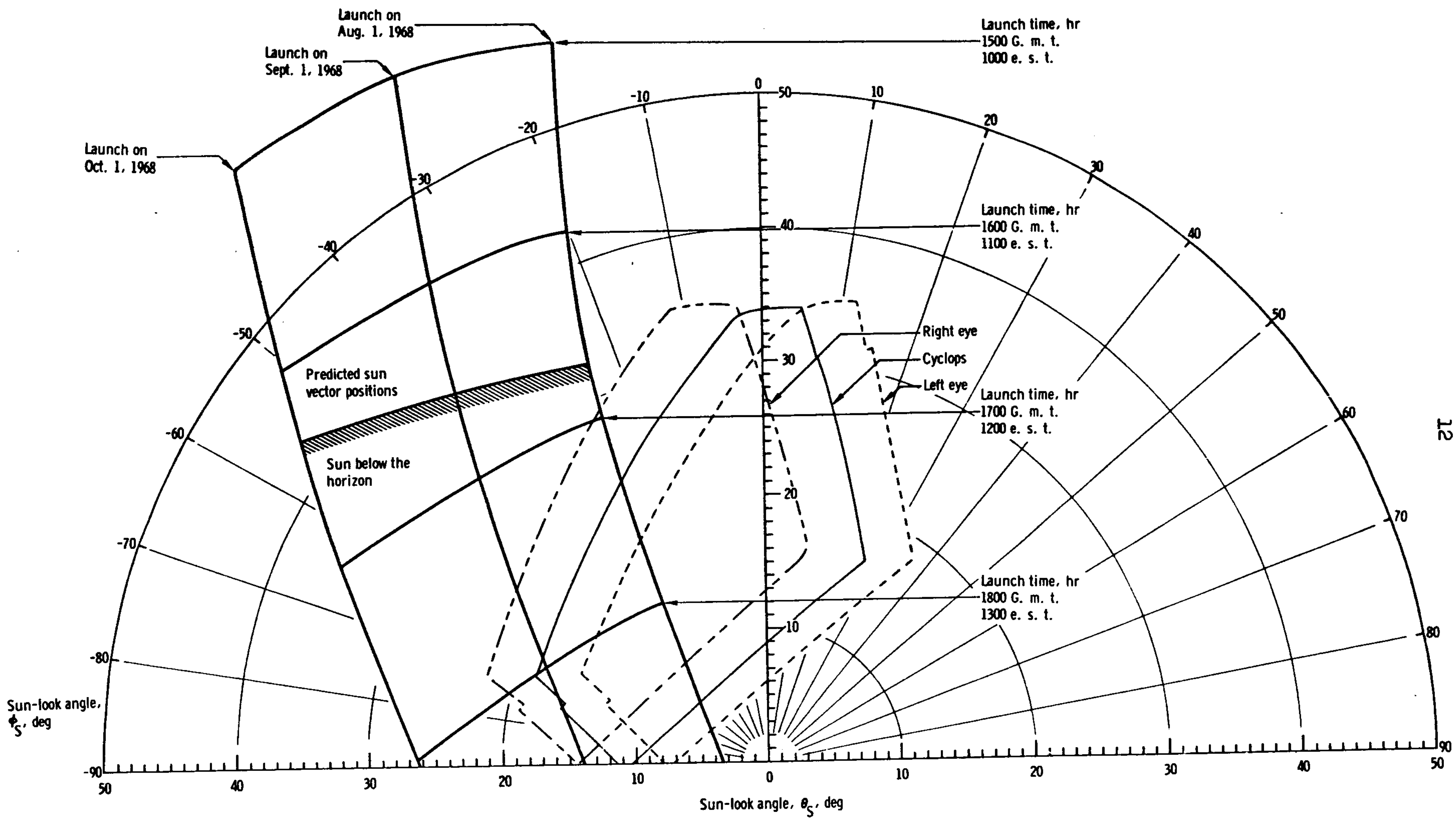
(a) Left forward viewing window.

Figure 4.- Predicted sun vector positions during nominal launch phase for 80th percentile man.



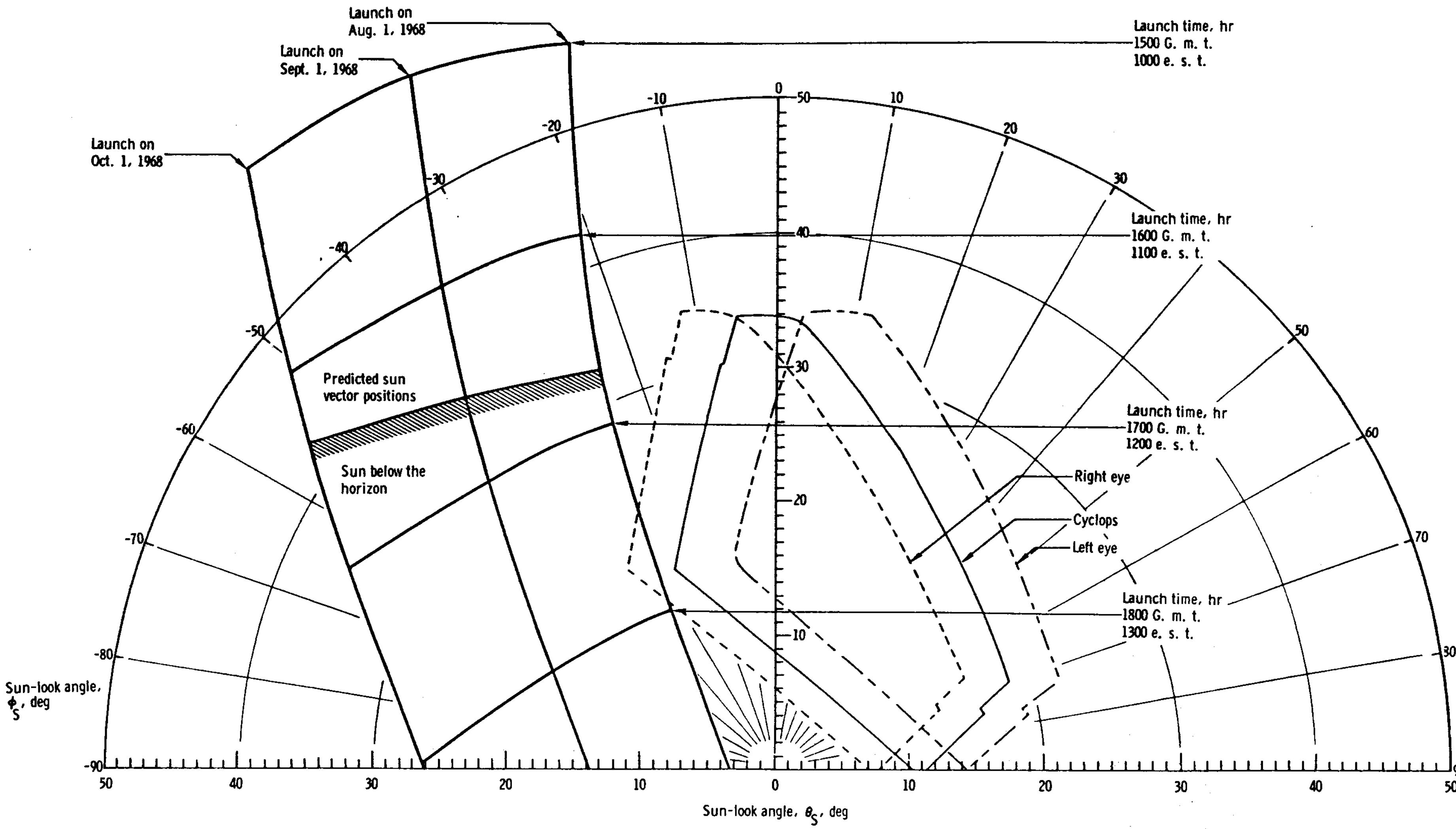
(b) Right forward viewing window.

Figure 4. - Concluded.



(a) Left forward viewing window.

Figure 5. - Predicted sun vector positions during maximum time delay fixed ΔV aborts for 80th percentile man.



(b) Right forward viewing window.

Figure 5. - Concluded.

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